NATIONAL NANOTECHNOLOGY INITIATIVE

The National Nanotechnology Initiative and Nanoscience User Facilities in the United States

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Co-chair
Nanoscale Science, Engineering, and Technology (NSET) Subcommittee
National Science and Technology Council

Scientific User Facilities Division
Office of Basic Energy Sciences
Office of Science
U.S. Department of Energy

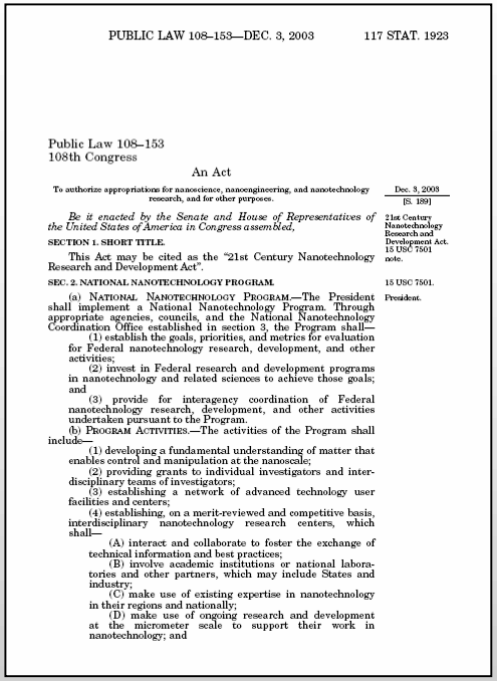
The Second Tri-National Workshop on Standards for Nanotechnology

NIST, Gaithersburg, MD *February 6, 2008*

NATIONAL NANOTECHNOLOGY INITIATIVE

What is the National Nanotechnology Initiative?

- The NNI is an interagency program that coordinates Federal nanoscale research and development activities and related efforts among various participating entities (currently 25)
- The NNI began in 2001 and its activities were codified and further defined in the 21st Century Nanotechnology Research and Development Act (Dec. 2003)
- Planned federal NNI expenditures are over $1.4 billion in FY 2008



PUBLIC LAW 108–153—DEC. 3, 2003 117 STAT. 1923

Public Law 108–153
108th Congress

An Act

To authorize appropriations for nanoscience, nanoengineering, and nanotechnology research, and for other purposes. Dec. 3, 2003 [S. 189]

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

21st Century Nanotechnology Research and Development Act. 15 USC 7501 note.

SECTION 1. SHORT TITLE.

This Act may be cited as the "21st Century Nanotechnology Research and Development Act".

SEC. 2. NATIONAL NANOTECHNOLOGY PROGRAM. 15 USC 7501.

(a) NATIONAL NANOTECHNOLOGY PROGRAM.—The President shall implement a National Nanotechnology Program. Through appropriate agencies, councils, and the National Nanotechnology Coordination Office established in section 3, the Program shall— President.

(1) establish the goals, priorities, and metrics for evaluation for Federal nanotechnology research, development, and other activities;

(2) invest in Federal research and development programs in nanotechnology and related sciences to achieve those goals; and

(3) provide for interagency coordination of Federal nanotechnology research, development, and other activities undertaken pursuant to the Program.

(b) PROGRAM ACTIVITIES.—The activities of the Program shall include—

(1) developing a fundamental understanding of matter that enables control and manipulation at the nanoscale;

(2) providing grants to individual investigators and interdisciplinary teams of investigators;

(3) establishing a network of advanced technology user facilities and centers;

(4) establishing, on a merit-reviewed and competitive basis, interdisciplinary nanotechnology research centers, which shall—

(A) interact and collaborate to foster the exchange of technical information and best practices;

(B) involve academic institutions or national laboratories and other partners, which may include States and industry;

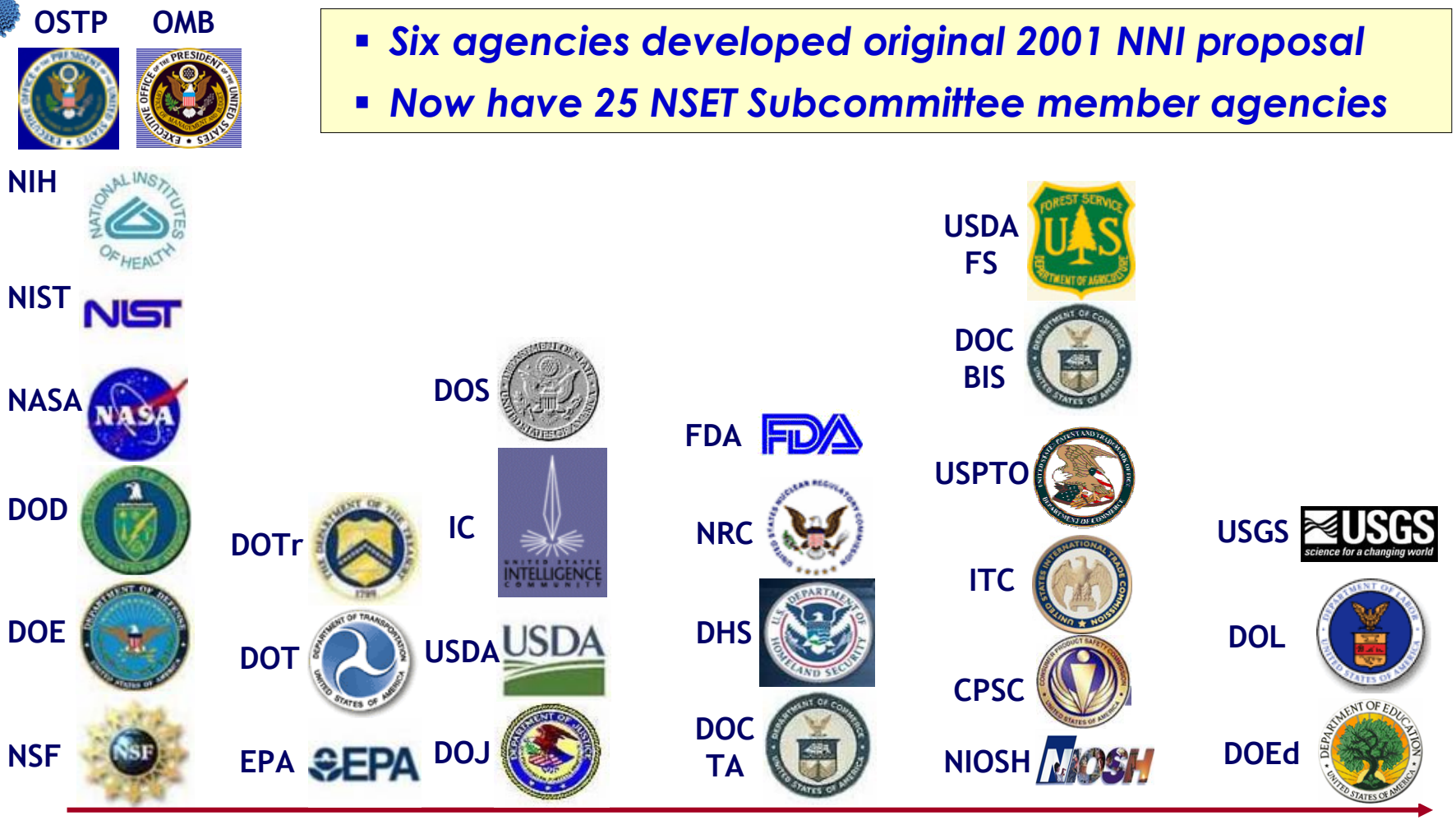
(C) make use of existing expertise in nanotechnology in their regions and nationally;

(D) make use of ongoing research and development at the micrometer scale to support their work in nanotechnology; and

NATIONAL NANOTECHNOLOGY INITIATIVE

Participating Agencies in the NNI

- *Six agencies developed original 2001 NNI proposal*
- *Now have 25 NSET Subcommittee member agencies*



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The NNI definition of "nanotechnology"

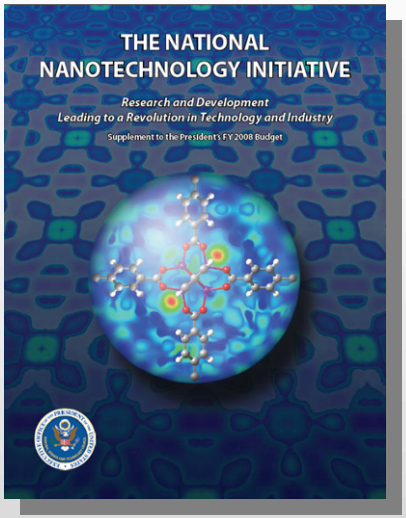
What is "nanotechnology"?

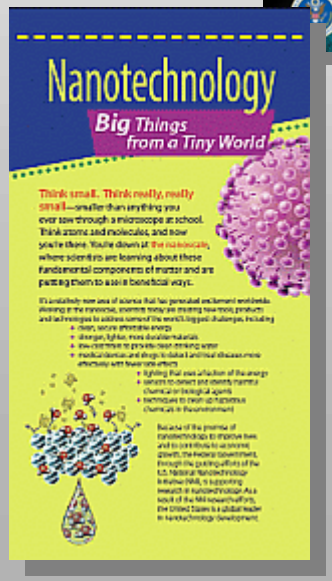
- ***Nanotechnology is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel application.***
- ***Nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale***

- ***With reference to the NNI, the term is meant to broadly encompass nanoscale science, engineering, and technology***
- ***Not just another step towards miniaturization; fundamental differences in physical, chemical, and biological behavior at this level compared to bulk materials or individual atoms/molecules***
  - ***quantum phenomena***
  - ***dominance of surfaces***
  - ***self-assembly***

NNI activities and documents inform agencies, report outcomes, and serve as resources

Supplement to the President's FY 2008 Budget

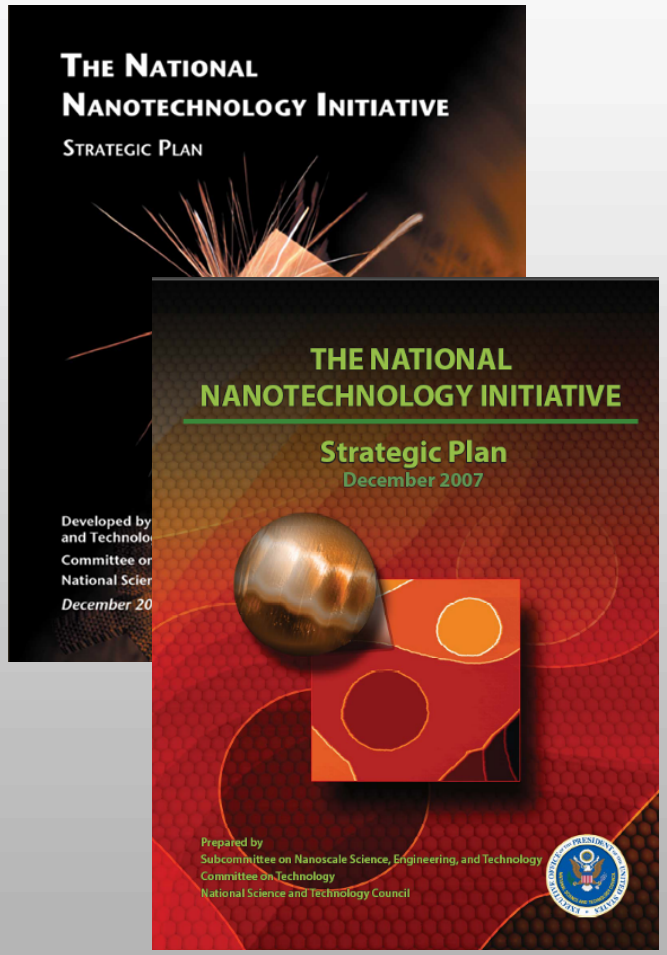




General brochure for a broad audience

NATIONAL NANOTECHNOLOGY INITIATIVE

Standards development in the NNI Strategic Plan



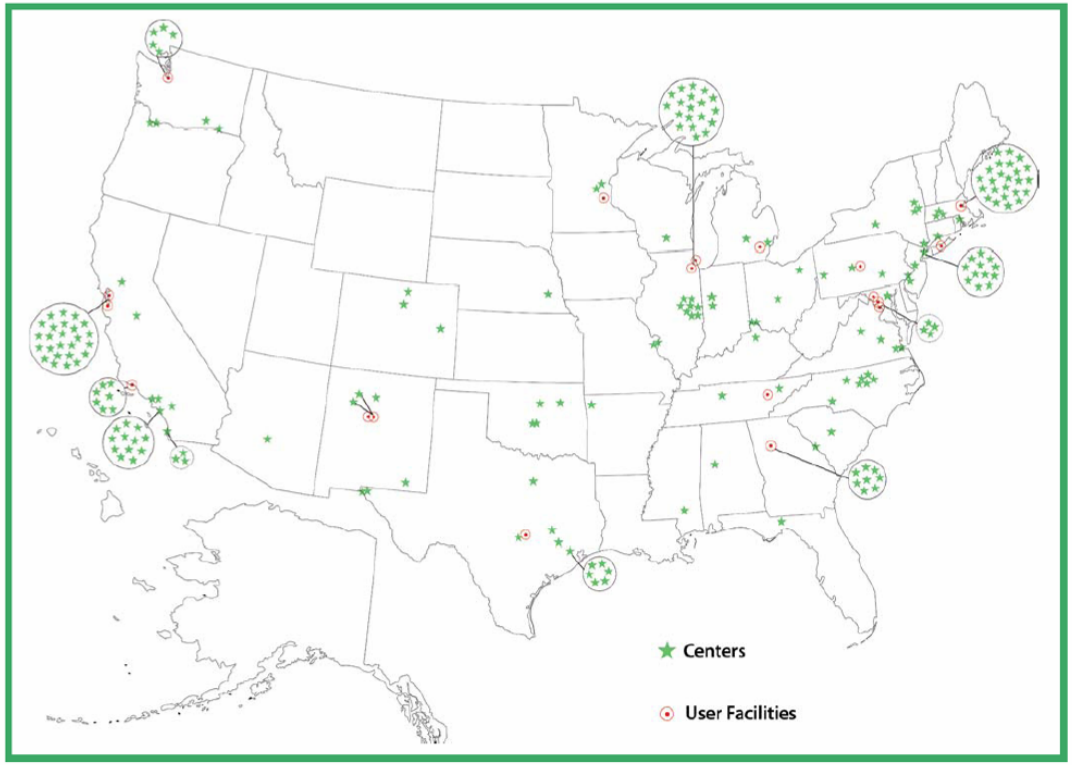
- ***Both the original (December 2004) and recently revised (December 2007) NNI Strategic Plans explicitly acknowledge the importance of standards. One of the eight NNI Program Component Areas is "Instrumentation Research, Metrology, and Standards for Nanotechnology," and the interagency coordinating group has explicitly supported ANSI, OECD, and other activities in this area.***

User Facilities for Nanoscience

- ***NNI user facilities provide critical scientific infrastructure. They make advanced experimental and theoretical capabilities accessible to researchers from academia, industry, and government laboratories; a vital component of this infrastructure are the scientific and technical staff members at these facilities.***

- ***User facilities are supported by various U.S. Federal agencies:***
  - *National Institute of Standards and Technology*
  - *National Institutes of Health*
  - *National Science Foundation*
  - *Department of Energy*

Figure 1. NNI-sponsored Centers and User Facilities (December 2007)

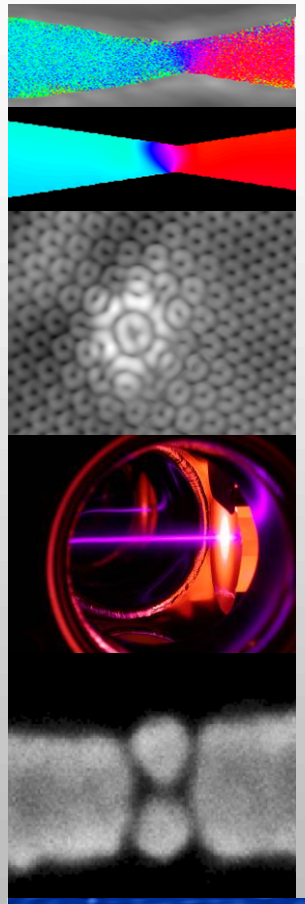


CNST – NIST's Center for Nanoscale Science and Technology

photo courtesy HDR Architecture, Inc./Steve Hall © Hedrich Blessing

- *Provides **measurement methods**, standards and technology to support all phases of nanotechnology development from discovery to production,*
- *develops and maintains a national shared use facility, **the Nanofab**, with state-of-the-art, nanoscale measurement and fabrication capabilities in Gaithersburg, MD*
- *applies a **multidisciplinary** approach to problem solving that involves partnering with industry, academia, and other government agencies,*
- *serves as a hub to **link the external nanotechnology community** to the vast measurement expertise that exists within the NIST Laboratories, and*
- *helps to **educate** the next generation of nanotechnologist.*

(For information see: http://cnst.nist.gov)



- ***Research Program*** *- Developing measurement capabilities for:*
  - *Future Electronics*
  - *Nanofabrication and Nanomanufacturing*
  - *Energy*
- ***The Nanofab*** *– A national, state-of-the-art, shared use facility for the measurement and fabrication of nanostructures both inside and outside of cleanrooms*
  - *19,000 sq ft cleanroom (8,000 sq ft class 100)*
  - *Advanced lithography and microscopy*
  - *Experienced staff to train users or operate the tools*
  - *Open to all users*

NATIONAL NANOTECHNOLOGY INITIATIVE

Nanotechnology Characterization Laboratory (of the National Cancer Institute in NIH)

NANOTECHNOLOGY CHARACTERIZATION LABORATORY

NCI Alliance for Nanotechnology in Cancer

NCL provides infrastructure support to the Alliance and to nanotech researchers - to overcome obstacles and translate 'nano' into the clinical realm

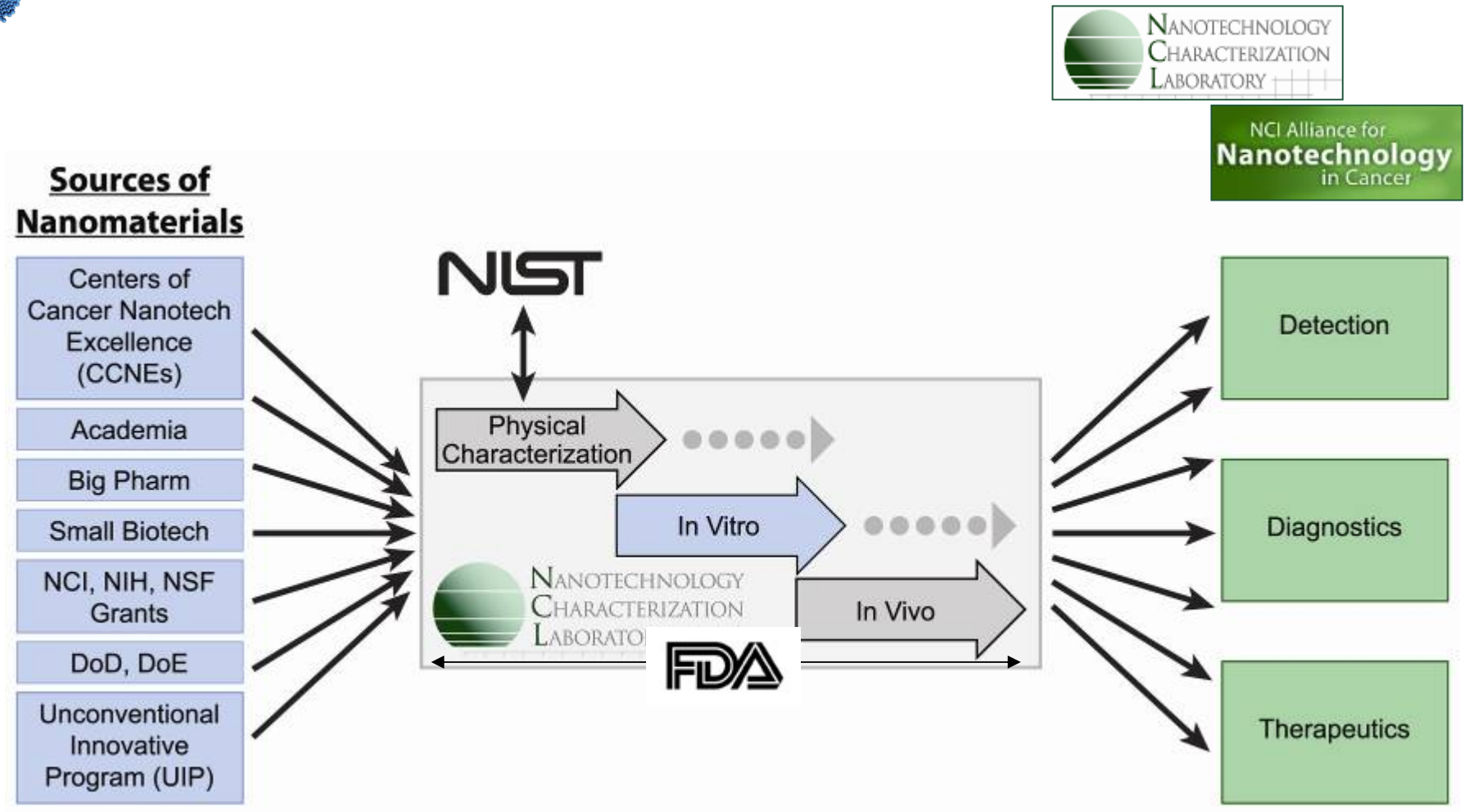
NCL Objectives

- ***Characterize nanoparticles using standardized methods***
- ***Conduct structure activity relationships studies***
- ***Facilitate regulatory review of nanotech constructs***
- ***Engage in educational and knowledge sharing efforts***

The NCL is a national resource available to investigators from academia, industry and government

ncl@ncifcrf.gov
http://ncl.cancer.gov

NCL Concept of Operations

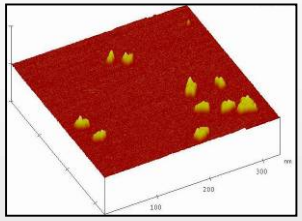


NCL is a formal collaboration between NCI, FDA and NIST

NCL Assay Cascade

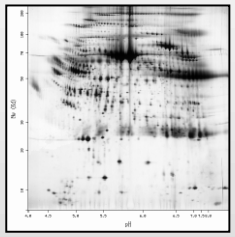
NANOTECHNOLOGY CHARACTERIZATION LABORATORY

NCI Alliance for Nanotechnology in Cancer



Physicochemical:

- *Size*
- *Shape*
- *Composition*
- *Molecular weight*
- *Surface chemistry*
- *Identity*
- *Purity*
- *Stability*
- *Solubility*



In Vitro:

- *Pharmacology*
- *Blood contact properties*
- *Immune cell function*
- *Cytotoxicity*
- *Mechanistic toxicology*
- *Sterility*

In Vivo:

- *ADME*
- *Safety*
- *Efficacy*

http://ncl.cancer.gov/assay_cascade.asp

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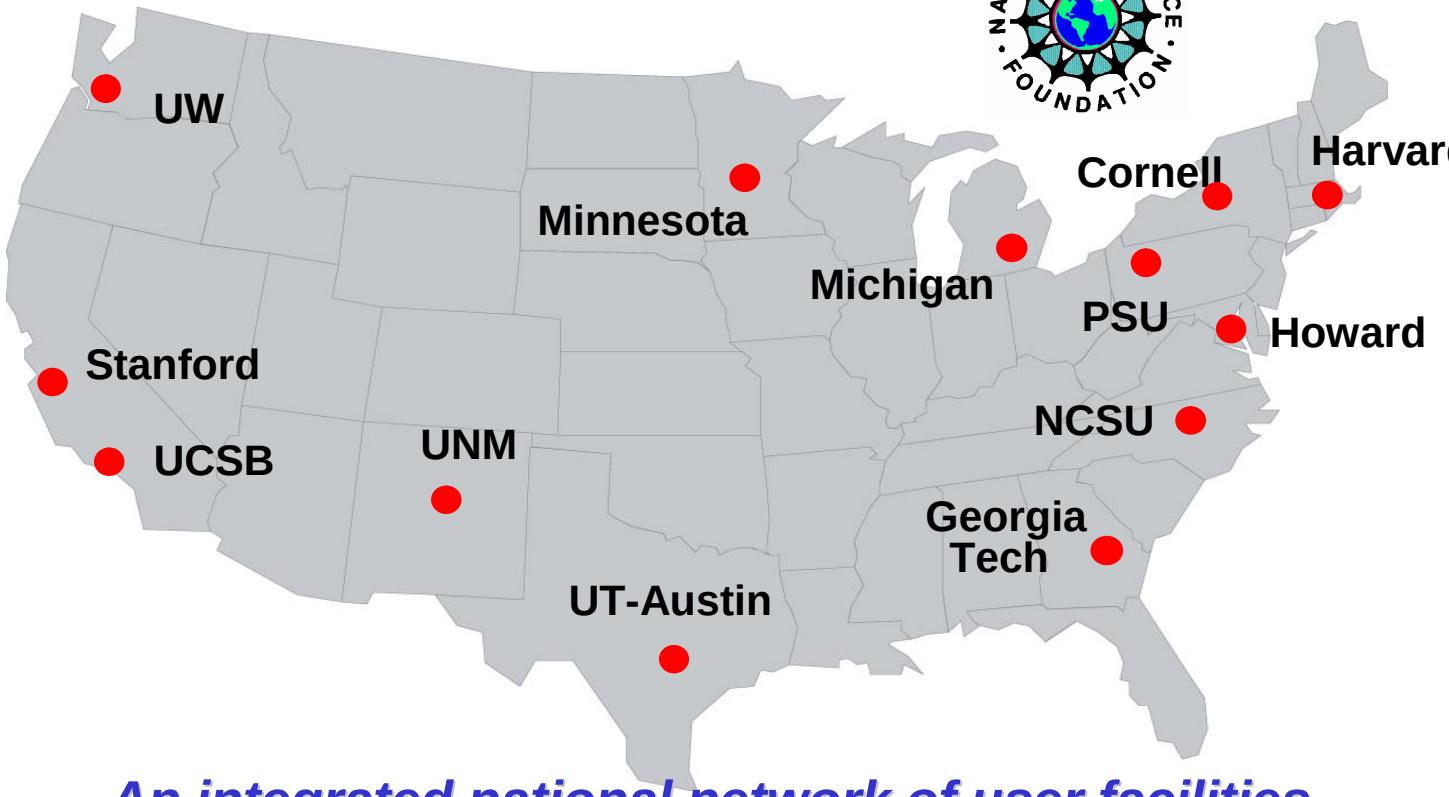
National Nanotechnology Infrastructure Network (NNIN)



NNIN
www.nnin.org
Nanoscale Science, Engineering & Technology

Cornell U (Lead)
Stanford U
U Michigan
Georgia Tech
U Washington
Penn State U
UC Santa Barbara
U Minnesota
U New Mexico
U Texas –Austin
Harvard U
Howard U
No. Carolina State U

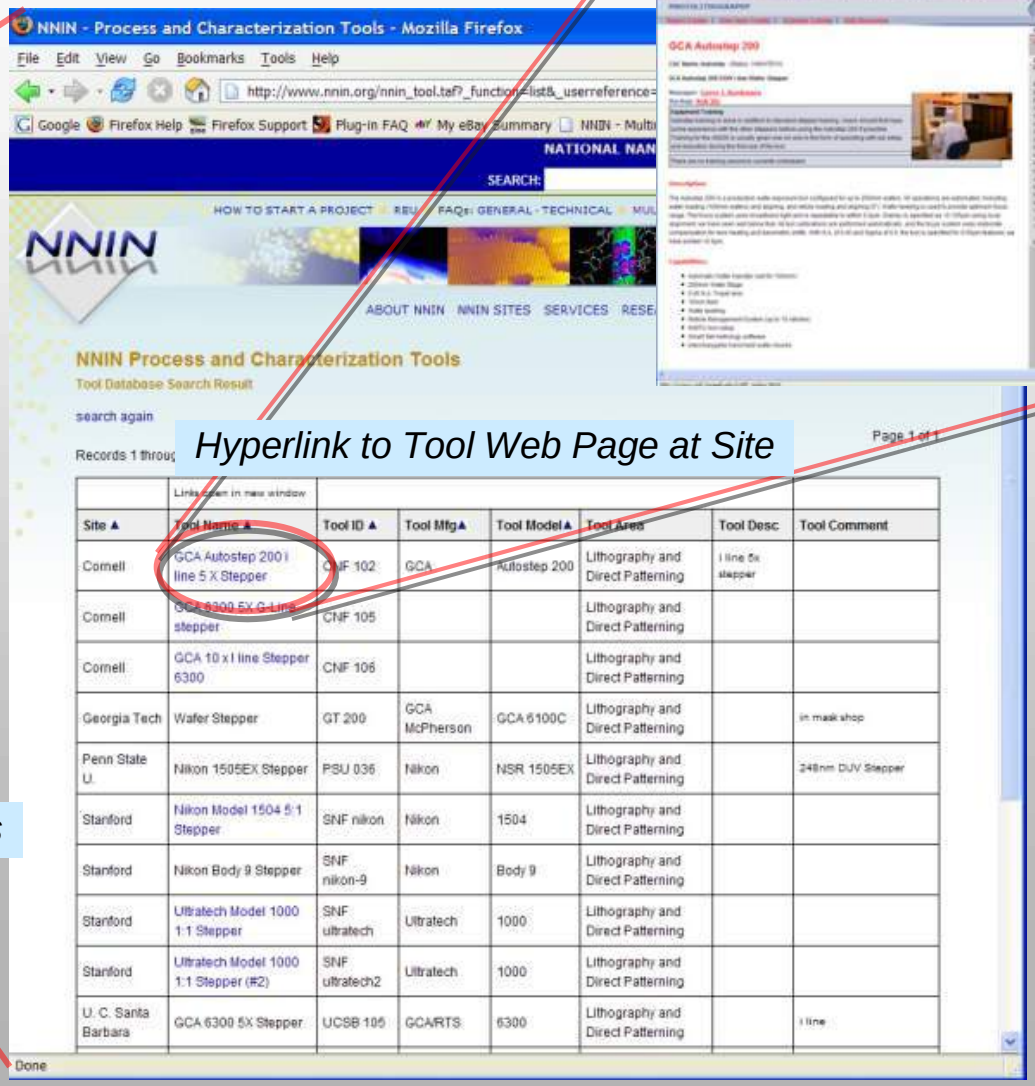
An integrated national network of user facilities providing researchers open access to resources, instrumentation, and expertise in all domains of nanoscale science, engineering, and technology

http://www.NNIN.org

NATIONAL NANOTECHNOLOGY INITIATIVE

NNIN Tool Database

Search Criteria



Site	Tool Name	Tool ID	Tool Mfg	Tool Model	Tool Area	Tool Desc	Tool Comment
Cornell	GCA Autostep 200 i line 5 X Stepper	CNF 102	GCA	Autostep 200	Lithography and Direct Patterning	i line 5x stepper	
Cornell	GCA 6300 5X G-I line stepper	CNF 105			Lithography and Direct Patterning		
Cornell	GCA 10 x I line Stepper 6300	CNF 106			Lithography and Direct Patterning		
Georgia Tech	Wafer Stepper	GT 200	GCA McPherson	GCA 6100C	Lithography and Direct Patterning		in mask shop
Penn State U.	Nikon 1505EX Stepper	PSU 036	Nikon	NSR 1505EX	Lithography and Direct Patterning		248nm DUV Stepper
Stanford	Nikon Model 1504 5:1 Stepper	SNF nikon	Nikon	1504	Lithography and Direct Patterning		
Stanford	Nikon Body 9 Stepper	SNF nikon-9	Nikon	Body 9	Lithography and Direct Patterning		
Stanford	Ultratech Model 1000 1:1 Stepper	SNF ultratech	Ultratech	1000	Lithography and Direct Patterning		
Stanford	Ultratech Model 1000 1:1 Stepper (#2)	SNF ultratech2	Ultratech	1000	Lithography and Direct Patterning		
U. C. Santa Barbara	GCA 6300 5X Stepper	UCSB 105	GCA/RTS	6300	Lithography and Direct Patterning		i line

Hyperlink to Tool Web Page at Site

Tools Availability at All Sites

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NNIN Education and Outreach

Workshops for
Journalists, Lawyers, etc
Technical Workshops
SEI Activities

Children's Magazine
School Activities
School visits

Equipment &
Process Training
Seminars
Workshops
Open Text Book

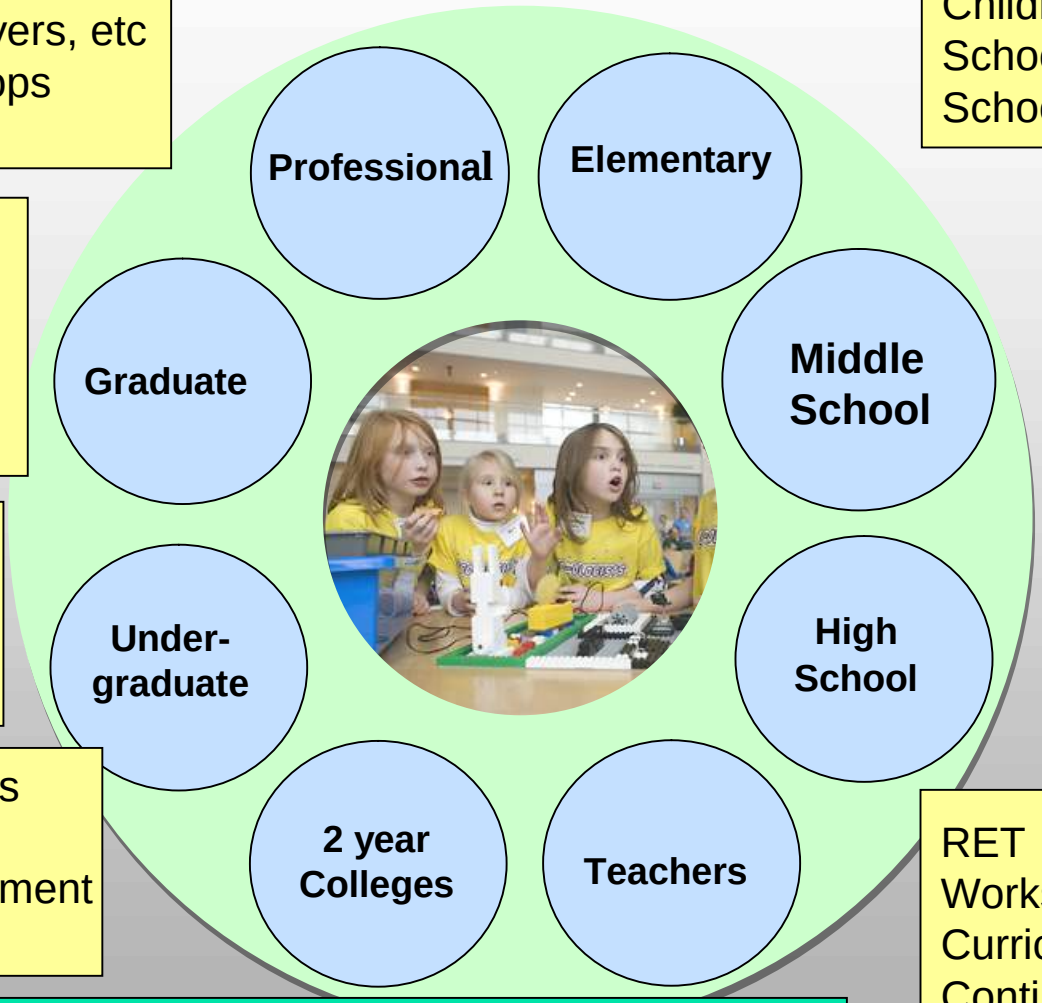
Chip Camps
Science Clubs
Curriculum Support
Nanoscience Kits
Travelling Van

REU
Workshops
Courses
Seminars

Internships
School Visits
Tours
Mentoring

Internship Programs
Workshops
Workforce Development
Course Support

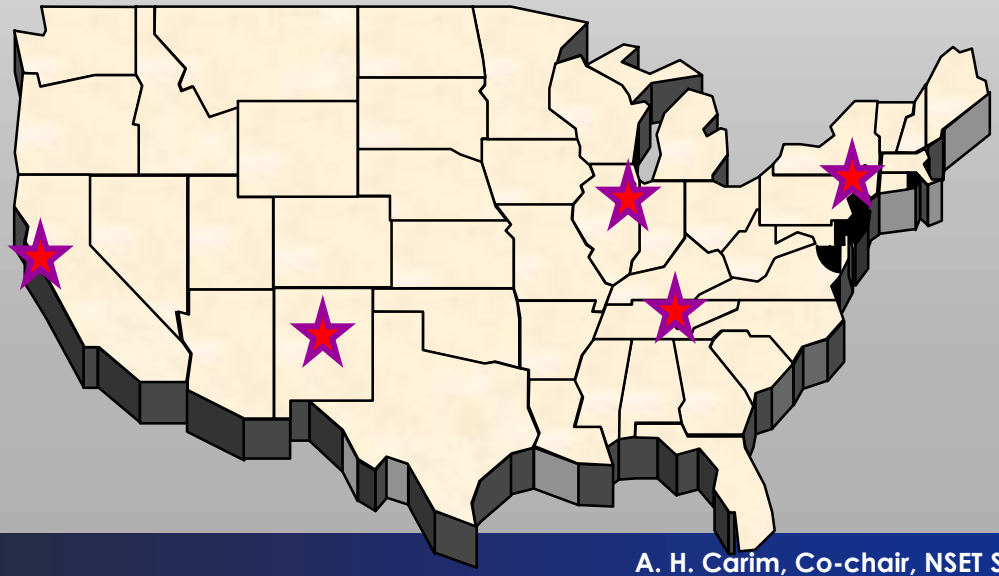
RET
Workshops
Curriculum Support
Continuing Education



National – Network wide activities, shared experience
Local – Site specific activities with focus on local issues

DOE's Nanoscale Science Research Centers: Basic Info

- *Research facilities for synthesis, processing, fabrication, analysis, characterization, and modeling of nanoscale materials*
- *Provide specialized equipment, unique tools, and support staff that are difficult for individual institutions to build and maintain*
- *Operated as user facilities; available to all researchers; access determined by peer review of proposals; cost recovery for proprietary work*
- *Co-located at DOE National Laboratories with existing major user facilities (synchrotron radiation light sources, neutron scattering facilities, other specialized facilities) to provide characterization and analysis capabilities*



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The five NSRCs are in operations and serving users

Center for Functional Nanomaterials
(Brookhaven National Laboratory, NY)

Molecular Foundry
(Lawrence Berkeley
National Laboratory, CA)

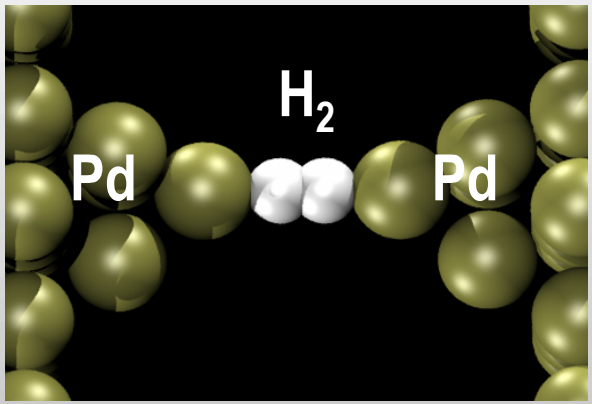
Center for Nanoscale Materials
(Argonne National Laboratory, IL)

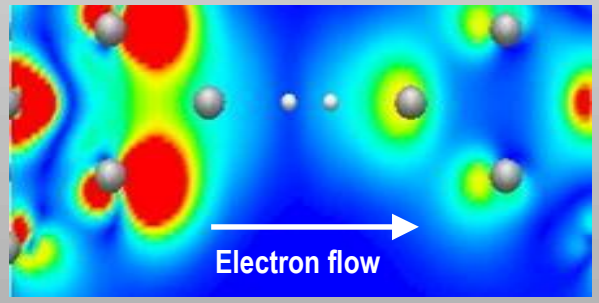
Center for Nanophase Materials Sciences
(Oak Ridge National Laboratory, TN)

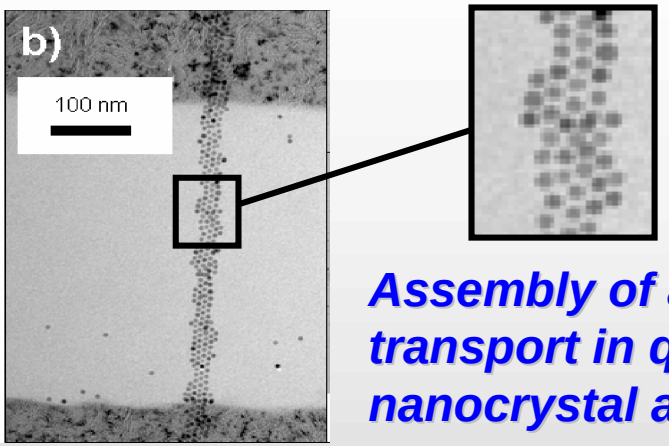
Center for Integrated Nanotechnologies
(Sandia & Los Alamos National Labs, NM)

NSRC Instruments, Expertise Support Cutting-edge Research

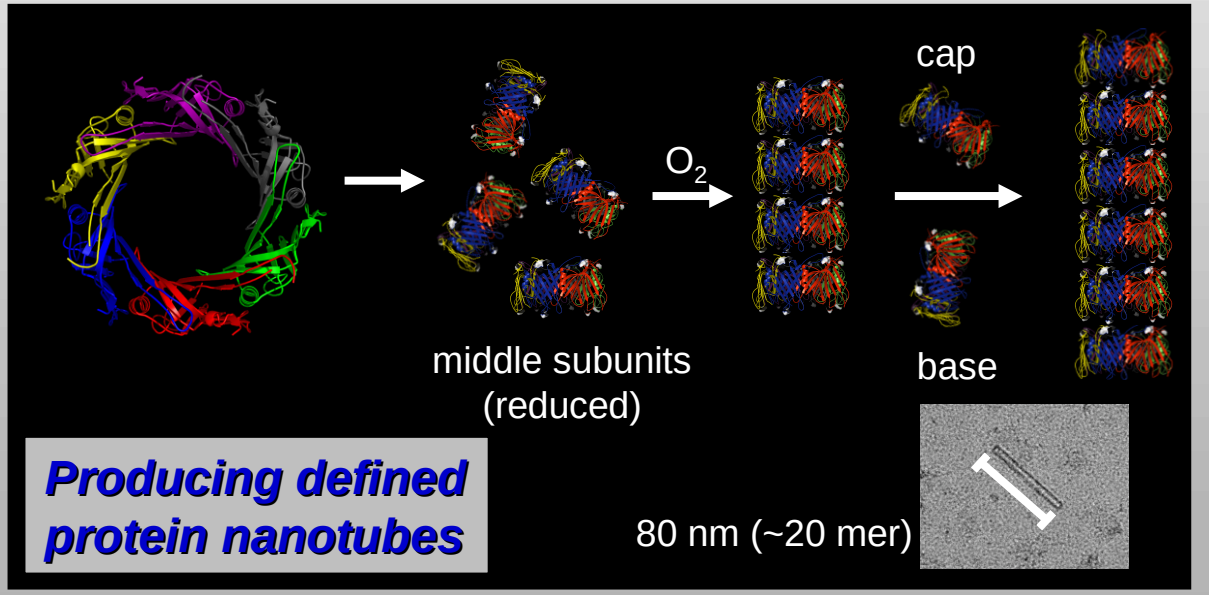
Calculating resistance across the smallest possible junction







Assembly of and charge transport in quasi-1D nanocrystal arrays



Producing defined protein nanotubes

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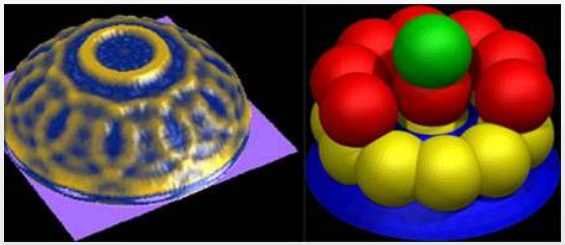
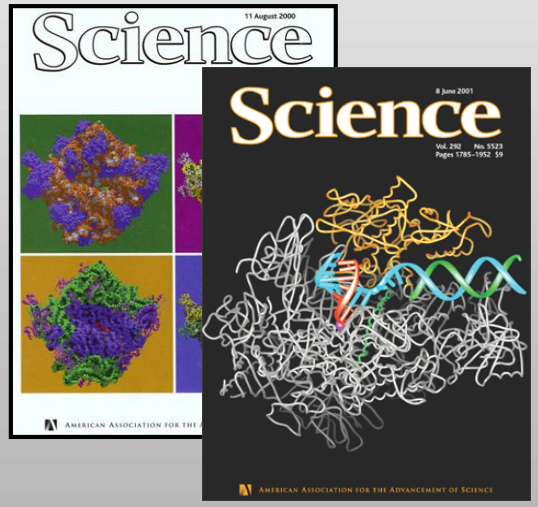
Seeing atoms:
National user facilities for probing materials at the atomic scale

X-ray scattering

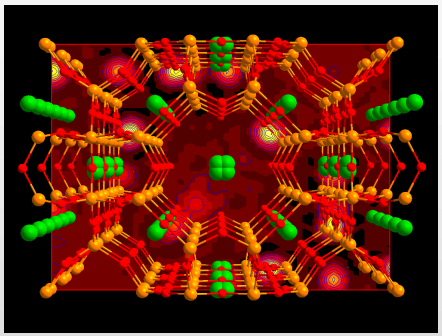


AlNiCo quasicrystal structure

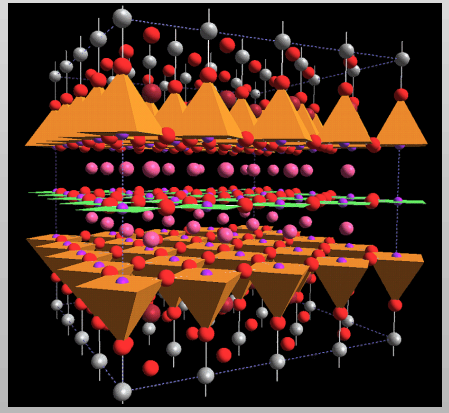


Molecular machines of life

Neutron scattering

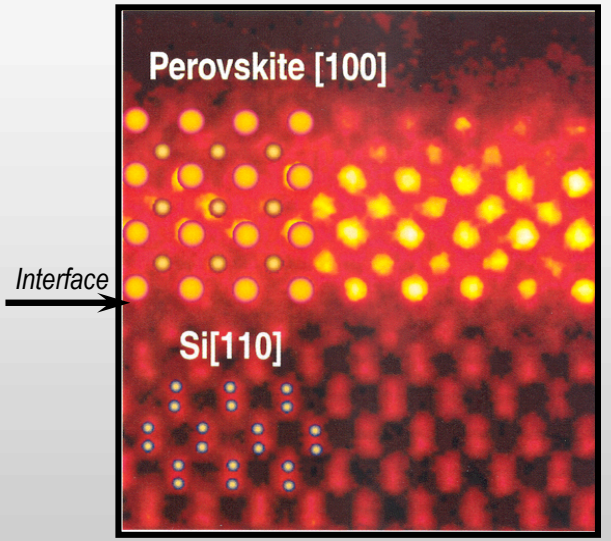


Zeolite catalyst



High Tc superconductor

Electron Scattering



Transmission electron microscope image showing an abrupt interface and low defect density for the ferroelectric $SrTiO_3$ on Si.

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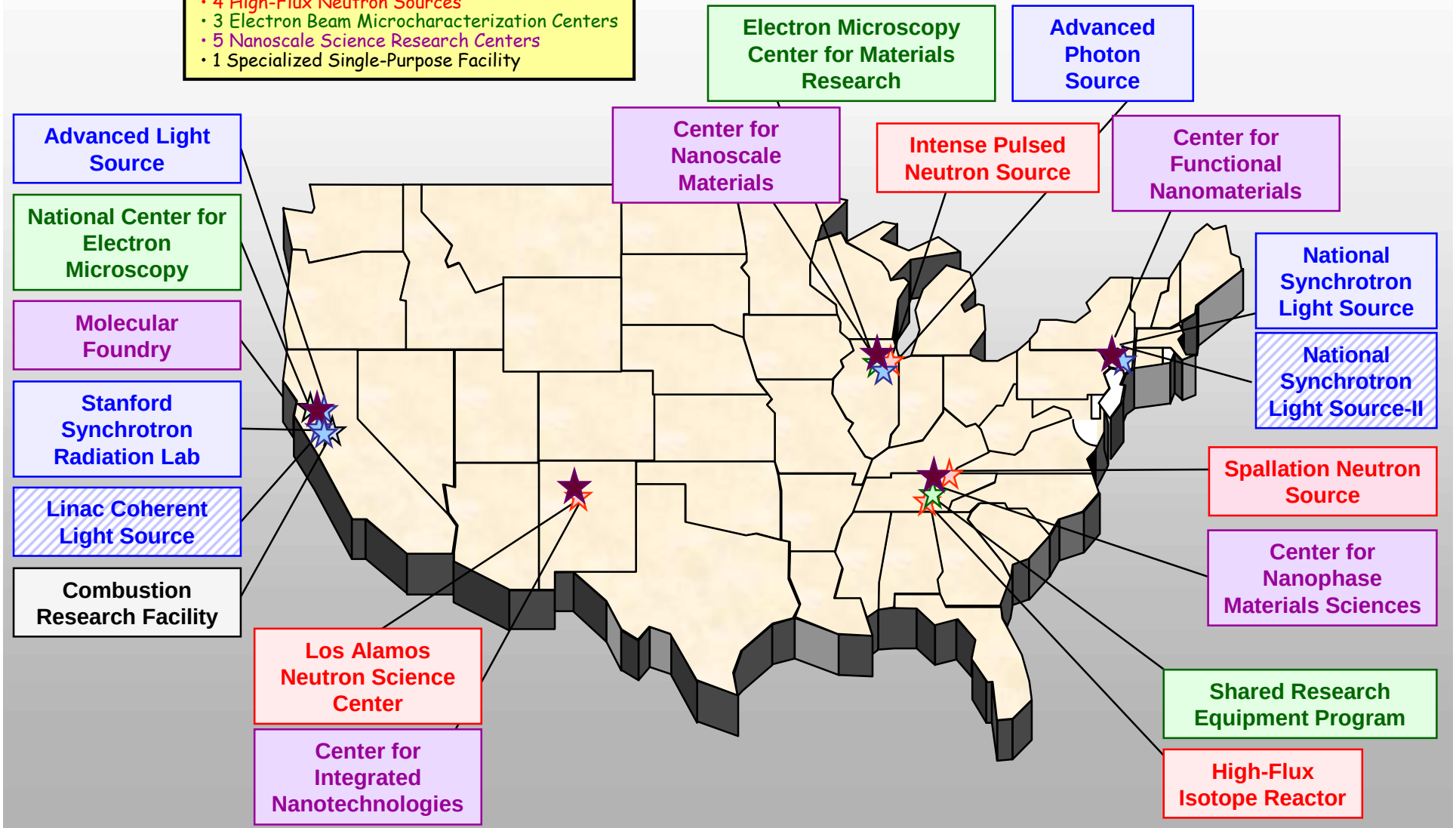
DOE Basic Energy Sciences Scientific User Facilities

- 4 Synchrotron Radiation Light Sources
- 2 additional Light Sources (Under construction)
- 4 High-Flux Neutron Sources
- 3 Electron Beam Microcharacterization Centers
- 5 Nanoscale Science Research Centers
- 1 Specialized Single-Purpose Facility



For more information on the NNI

- **http://nano.gov**